DEPARTMENT OF THE ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY, CORPS OF ENGINEERS
HANOVER, NEW HAMPSHIRE 03755

August 12, 1983

Snow and Ice Branch

Mr. Charles E. Smith
Minerals Management Service
MMS-Mail Stop 647
12203 Sunrise Valley Drive
Reston, Virginia 22091

Dear Charles:

Persuant to our discussion on ice stress measurements in Anchorage, 26 July 1983, please find enclosed some general comments on determining ice forces on offshore structures. While conservative estimates of ice loads on offshore structures can be obtained from analytical models and model tests, ice stress measurements are needed to obtain actual ice load values as well as to define the stress distribution and large scale mechanical properties of the ice cover. Should you wish to discuss this subject at greater length, please do not hesitate to call me.

Sincerely,

Gordon

Gordon F.N. Cox
Geophysicist
Snow and Ice Branch

Enclosure

CF: Dr. W.M. Sackinger (w/enclosure)

ICE FORCES ON OFFSHORE STRUCTURES

Estimates of the magnitude of ice forces on offshore structures can be obtained from analytical models, model tests, and field measurements. Generally, information from all three approaches is considered in design, as each method has its strengths and weaknesses.

Analytical models take into consideration the ice-structure geometry, environmental driving forces, and assume a constitutive law for the ice based on mechanical property tests. Frequently, finite element and plastic limit analyses are employed. All analytical models suffer from a lack of appropriate test data on the mechanical properties of the ice, and a detailed description of actual ice failure modes for the structure and ice feature in question. Thus, such models generally bound, rather than predict ice forces, since the amount of information needed to establish a bound is substantially less than that required for a detail description of the ice-structure interaction. However, by making certain assumptions, upper bound ice force estimates can be obtained relatively inexpensively using analytical methods.

Model tests are particularly useful as they provide data for verifying or tuning analytical models. Due to the difficulty of properly scaling all the mechanical properties of the ice, model basin tests are generally restricted to one ice failure mode, usually crushing, bending, or buckling. At this time model tests cannot be used to estimate ice forces associated with mix-mode failure, such as creation of a rubble pile around a structure.

Consequently, model tests and analytical models are limited in scope. This results in conservative assumptions and probably over-design.

The most direct method of determining ice forces on offshore structures is to measure actual ice forces in the field. This can be accomplished by either instrumenting the structure of by placing ice stress sensors in the ice around the structure. Due to high logistics costs in the arctic, field measurements are expensive to obtain and we are not guaranteed to measure "design" ice loads due to less than extreme driving forces during the measurement program. However, the direct measurements do take into consideration the large scale mechanical properties and mix-mode failure of the ice cover.

In addition to the large scale mechanical properties of the ice cover, and ice-strucutre geometry, ice loads on offshore structures are also governed by the environmental driving forces. The traction of winds and currents on the ice cover cause the ice to move. If the forces are sufficient they cause the ice to fail against the structure.

In order to obtain "design" ice stress measurements, it is necessary to monitor stresses in the ice around a structure for a number of years to determine the probability or return period of a given ice stress event. Based on analyses of ice movement data for the Beaufort Sea, it appears that a minimum of five years (winters) of stress measurement are required to provide rough statistics from which extreme events can be extrapolated. While several years of measurement are required to begin considering ice forces in probablistic terms, much can be learned about the stress distribution in the ice cover during a one winter program. Important problems that can be addressed in such a program are: the nature of the vertical stress distribution in the ice; how the stress varys around the structure; and the relationship between the far field geophysical stress and local stress around the structure. Such findings would serve as valuable input to analytical ice force prediction models.